DESIS Imaging Spectrometer data access and synergistic use with other ISS Earth observing instruments

Uta Heiden, Martin Bachmann, Kevin Alonso, Emiliano Carmona, Daniele Cerra, Daniele Dietrich, Maximilian Langheinrich, Raquel de Los Reyes, Rupert Mueller, Nicole Pinnel, Valentin Ziel

German Aerospace Center (DLR)

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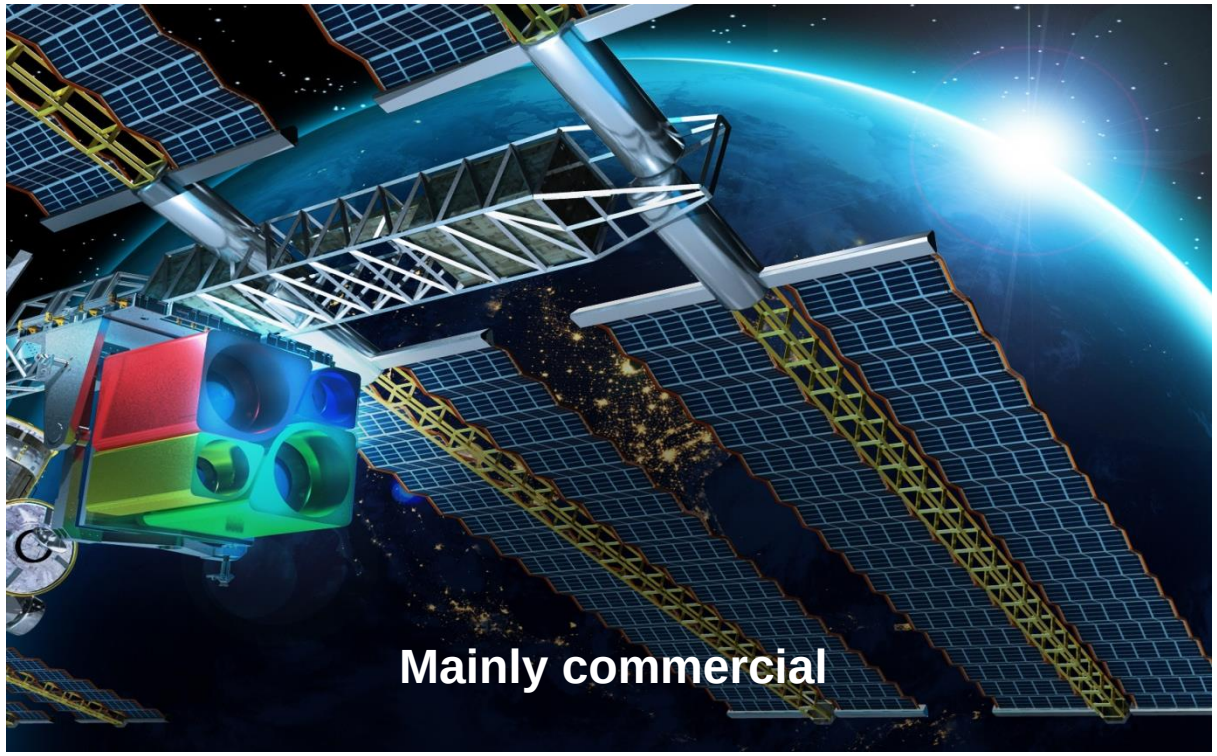
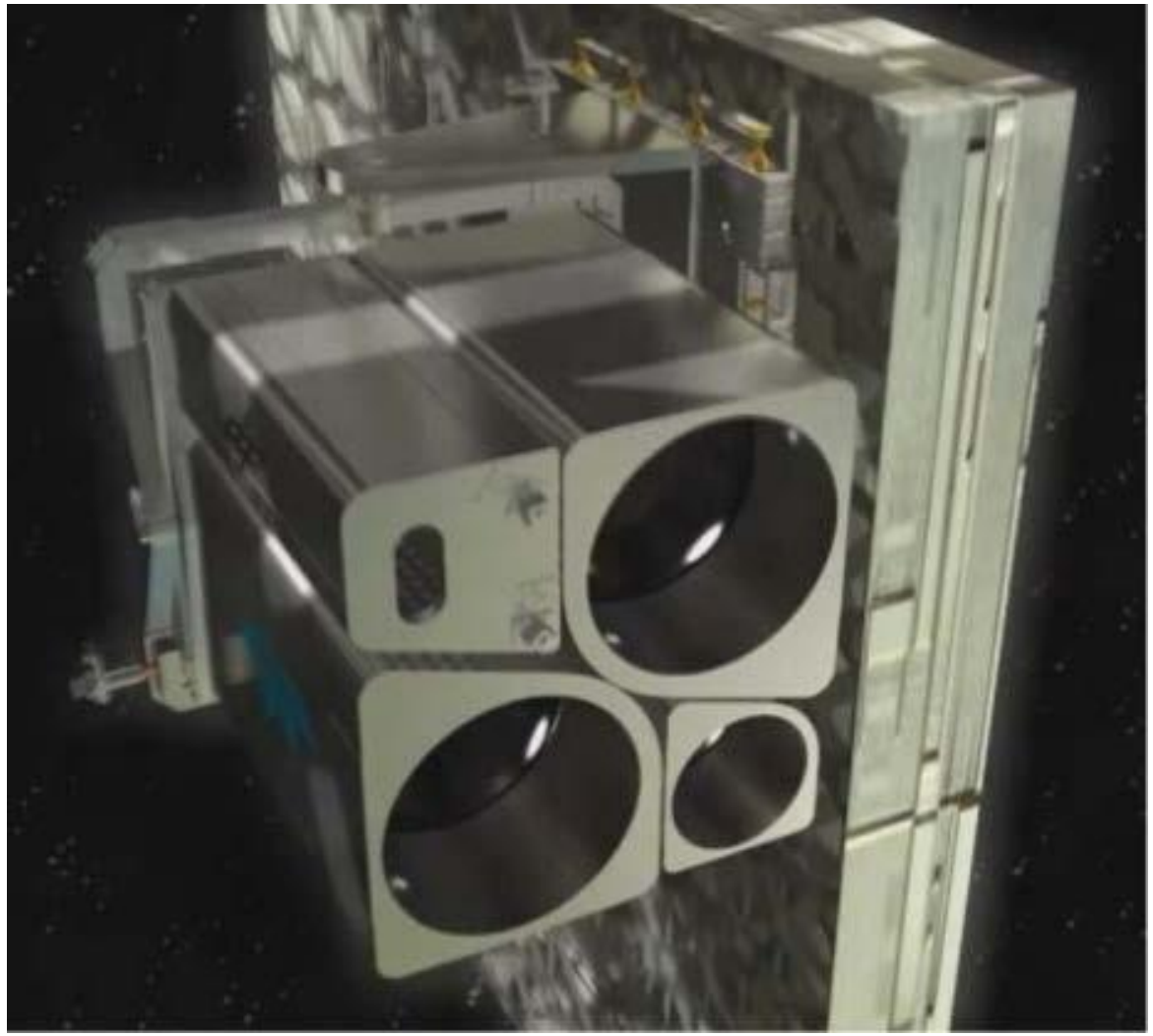
DESIS Mission Overview



Teledyne Brown Engineering and **DLR** have partnered to built and operate the DLR Earth Sensing Imaging Spectrometer (DESIS)

- Mounted on Multi-User System for Earth Sensing (MUSES) Platform on the ISS
- MUSES provides accommodations for two large and two small hosted payloads and core services like:
  - Position via GPS (1 Hz)
  - Attitude via Startracker + MIMU (10 Hz)
  - Master time (acc. <150 µsec)
  - 2 Gimbals ±25° for/back; 45° backboard; 5° starboard
  - Downlink 225 Gbit / day Ku band
- The hyperspectral sensor DESIS is currently the first payload and build by DLR
- DLR is responsible to establish the Ground Segment and licenses the SW processors to Teledyne
- Focal Plane Array same as for EnMAP => DESIS can be also regarded as a precursor of EnMAP

DESIS Mission Overview



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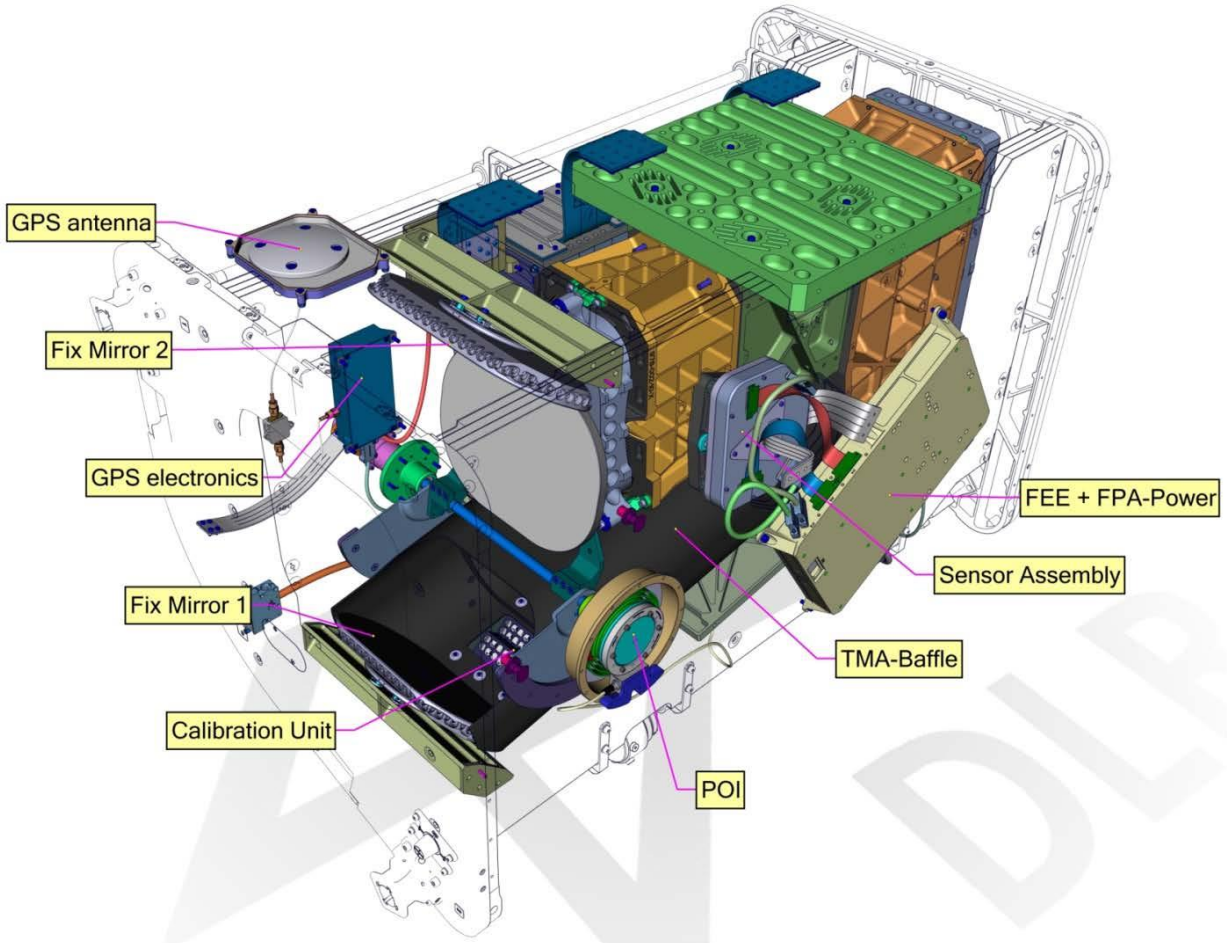

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DESIS Mission and Instrument Specification

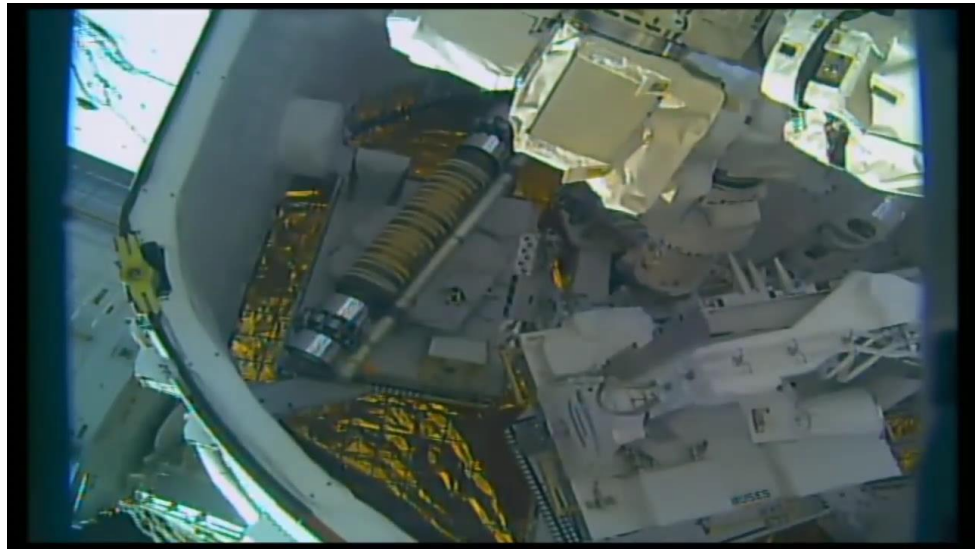
Mission Instrument	ISS/MUSES DESIS
Off-nadir tilting (across-track, along-track)	-45° (backboard) to +5° (starboard), -40° to +40° (by MUSES and DESIS)
Spectral range	400 nm to 1000 nm
Spectral (res., acc.)	2.55 nm, (*)
Radiometry (res., acc.)	13 bits, (*)
Spatial (res., swath)	30 m, 30 km (@ 400 km)
SNR (signal-to-noise)	205 (no bin.)/406 (4 bin.) @ 550 nm
Instrument (mass)	93 kg
Capacity (km, storage)	2360 km per day, 225 GBit

Mission Instrument	ISS/MUSES DESIS
Target lifetime	2018-2023
Satellite (mass, dimension, usage)	455 t, 109.0×97.9×27.5 m^3 (multi-purpose)
Orbit (type, local time at equator, inclination, height, repeat cycle)	not Sun-synchronous, various, 51.6°, 320 km to 430 km, no repeat cycle
Coverage	55° N to 52° S
Revisit frequency	3 to 5 days (average)

Acquisition modes:

- Earth – user deliverable product
- BRDF (e.g. -15°, 0°, +15°) - user deliverable product
- Forward Motion Compensation – experimental
- Var. HW binning and Gain
- Calibration
- Dark current
- Rolling / global shutter

DESIS Milestones



2014 / 2015	MUSES / DESIS mission planning starts
7. June 2017	MUSES installed on ISS
29. June 2018	DESIS launched from Cape Canaveral to ISS via SpaceX Dragon
27./28. August 2018	Unpacking of DESIS and installation in MUSES
2. September 2018	First DESIS Image Start Commissioning Phase
Sept. – Dec. 2018	DLR Ground Segment development Public Relations
16. December 2018	DLR-GS finalized Commissioning (SW Licensing) • Commissioning Report (Req. fullfilled) • SW Delivery to Teledyne

DESIS Milestones - Why still not operational?

- No valid NOAA license for scientific community available yet
- Teledyne clarifies with NOAA whether there are restrictions on foreign DLR employees using DESIS data and if and how non-DLR employees can get data
- NOAA license for 2.55 and 5.1 nm data only for DLR (waiver to be extended to selected DLR partners)
- User License for Utilization of DESIS Data for Scientific Use in work (depends also on NOAA License)
- Leaving Commissioning Phase, but some remaining tasks
- Commercial Data delivery already started

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Falkland Island
51°39´26.70´´S 60°21´07.11´´W
2018.09.10 19:27:41 UTC
Blue-Green-Red = 463 nm, 553 nm und 639 nm
Georeferenced Data Cube
Byron Sound
Hill Cove
Roy Cove
Chartres
Dunnose Head
Queen Charlotte Bay
Spring Point
West Falkland
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2018 DigitalGlobe
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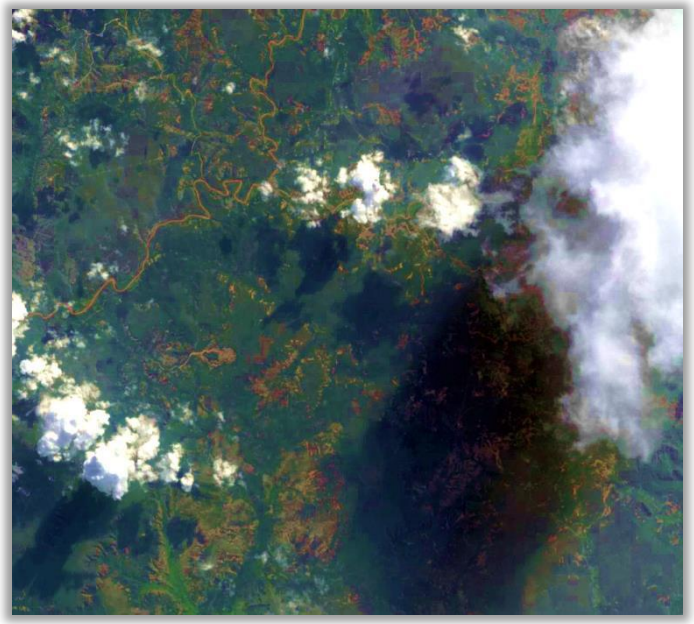
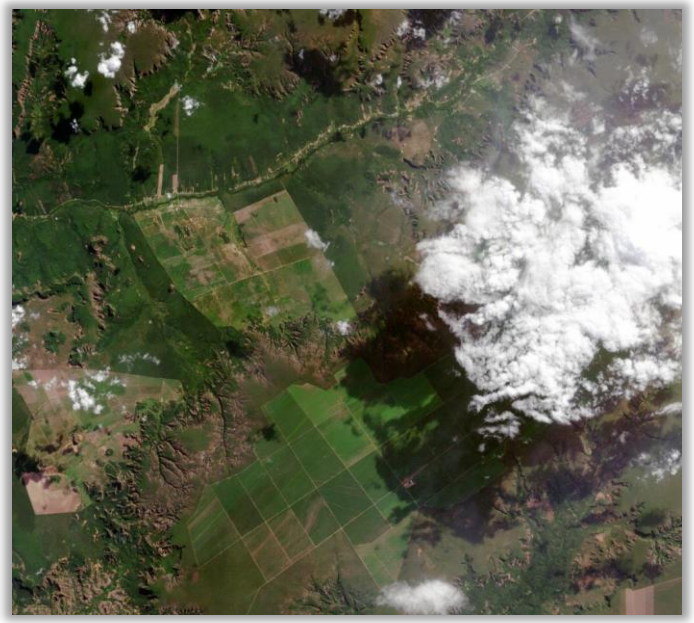
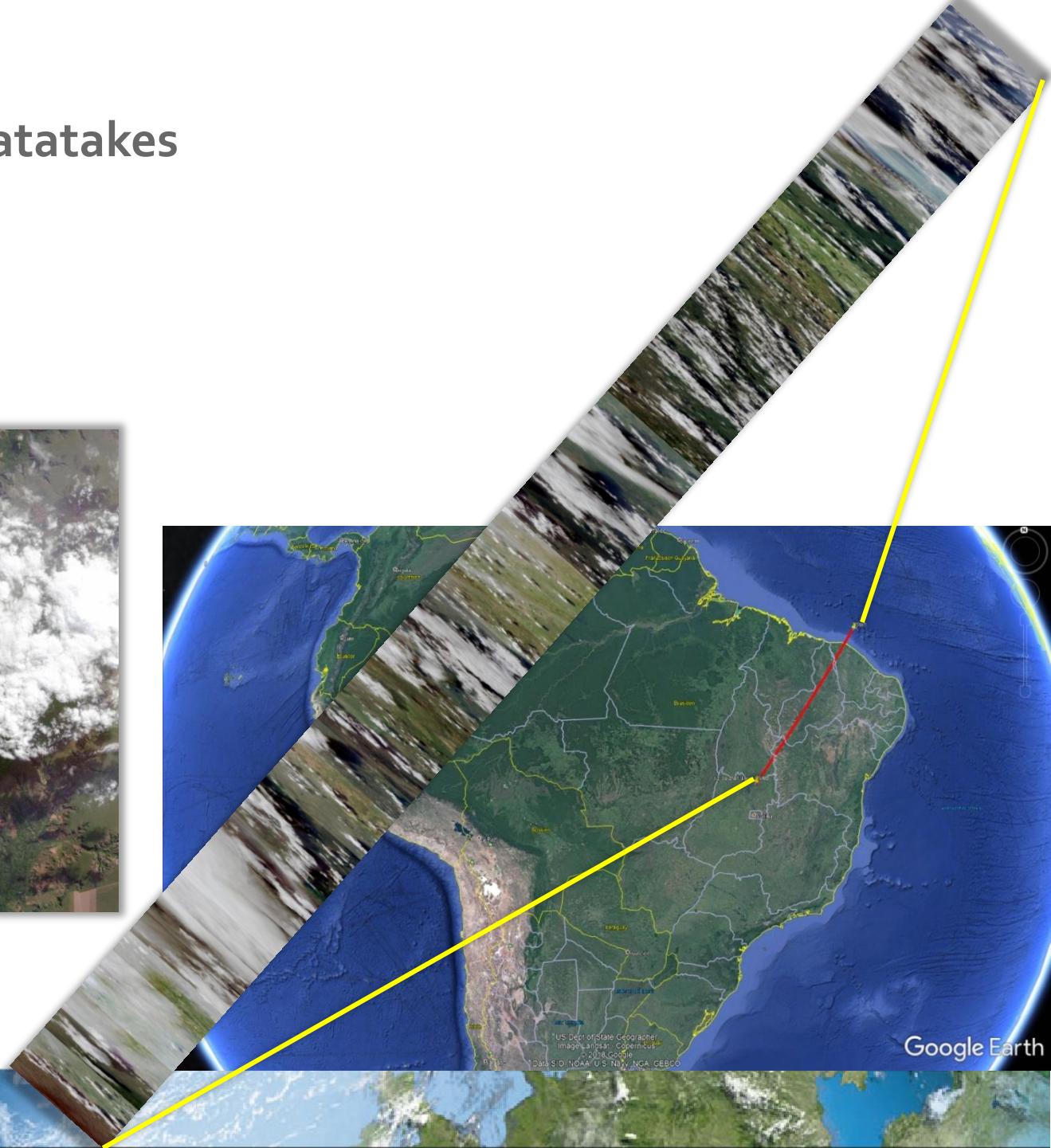
Also including first applications – Brazil datatakes (context: Brumadinho mining accident)

- Datatake of 55 tiles, ~ 1600 km lengths,
- Image cube: 56.320 pix * 1024 pix * 235 bands







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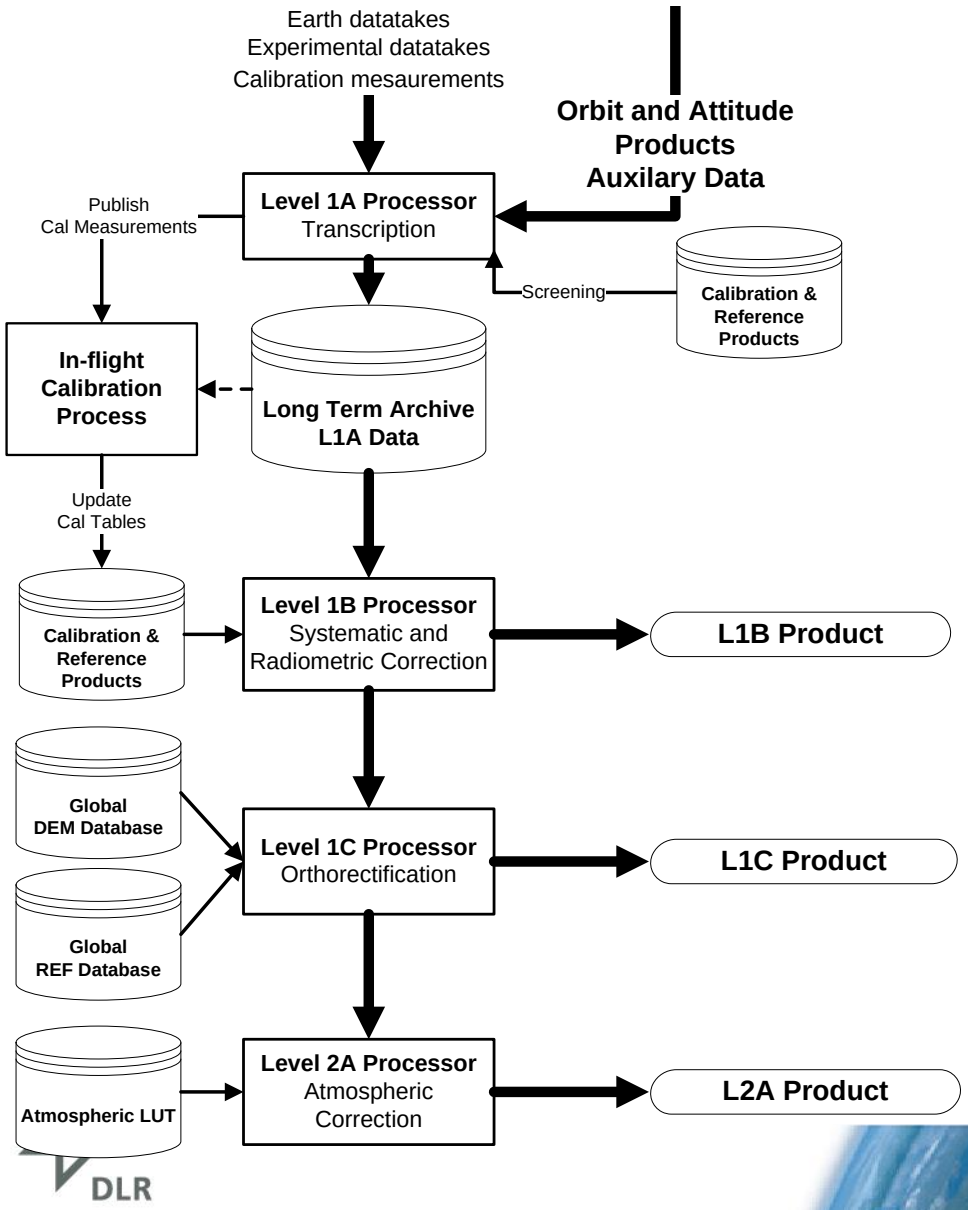
DESIS Data Processing



Products:

Level 0 (L0)

- Raw data (Datatakes up 100 tiles 30x30 km², trajectory files, DC)

Level 1A (L1A)

- Tiled images, browse image, metadata, quality flags <= archived.

Level 1B (L1B)*

- Top of Atmosphere (TOA) radiance (W.m-2.sr-1.µm-1)
- Systematic and radiometric correction (rolling shutter, smile, suspicious pixels,….)
- All metadata attached for further processing

Level 1C (L1C)*

- Level 1B data ortho-rectified, re-sampled to a specified grid
- Global DEM (Aster GDEM v2), sensor model refinement using global reference image (Landsat-8 PAN with acc. 18m CE90)

Level 2A (L2A)*

- Ground surface reflectance (i.e. after atmospheric corrections)
- With and w/o terrain correction

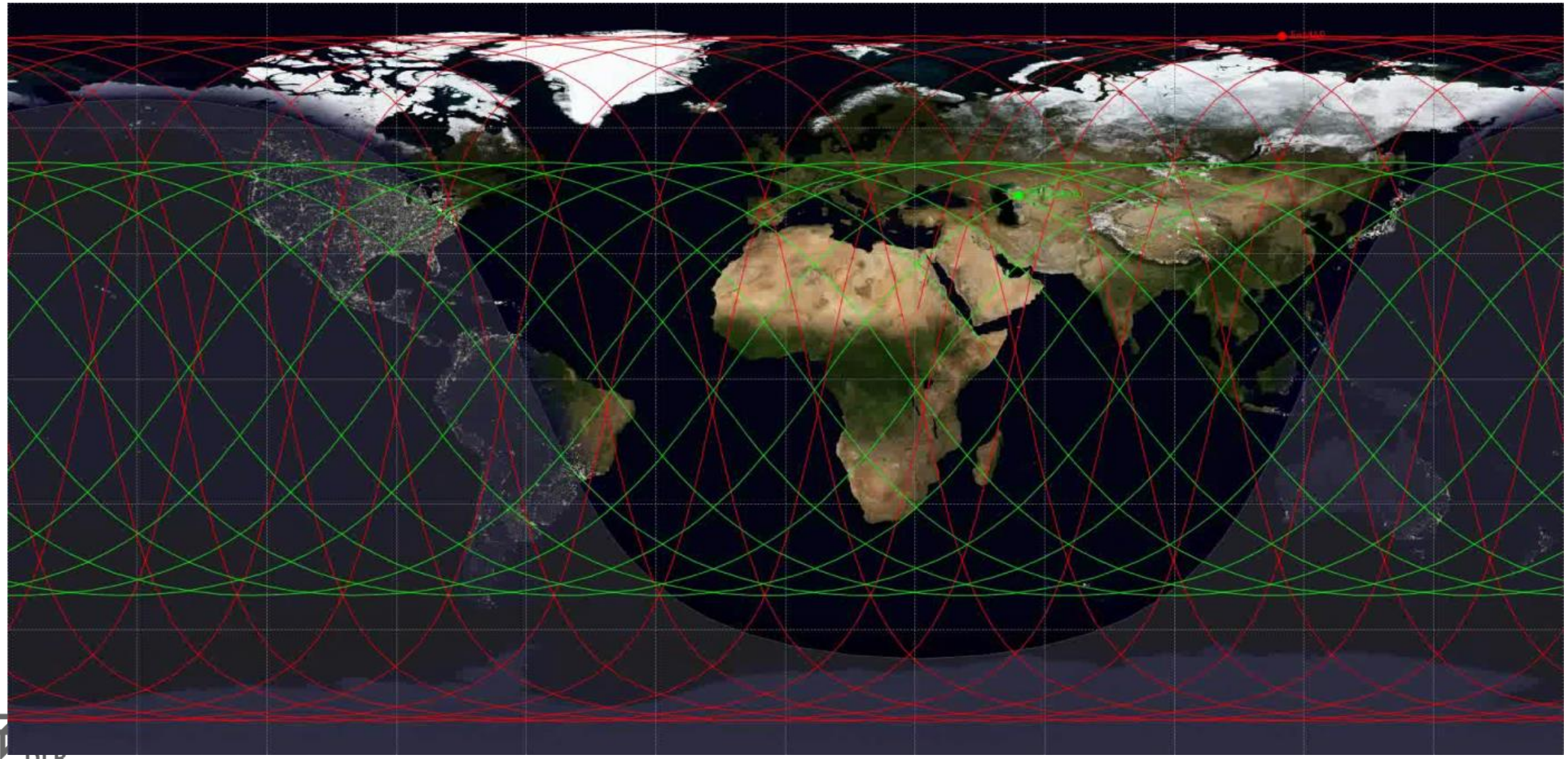
Processors at the Ground Segments

- Fully automated
- Run ‘on-request’ over archived data
- Two instances: one at Teledyne (Amazon Cloud), one at DLR. Same processing

* Delivery product

ISS Orbit constraints

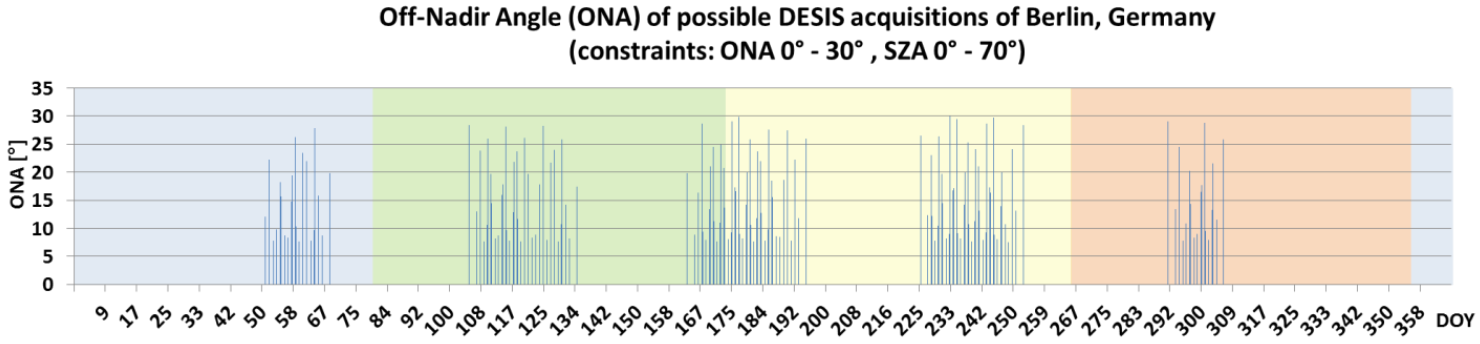
ISS (~ 400km), non-sun-synchronous orbit
Covers 55° N to 52° S
Tilting options: -45° (backboard) to +5° (starboard),
-40° to +40° (along track)

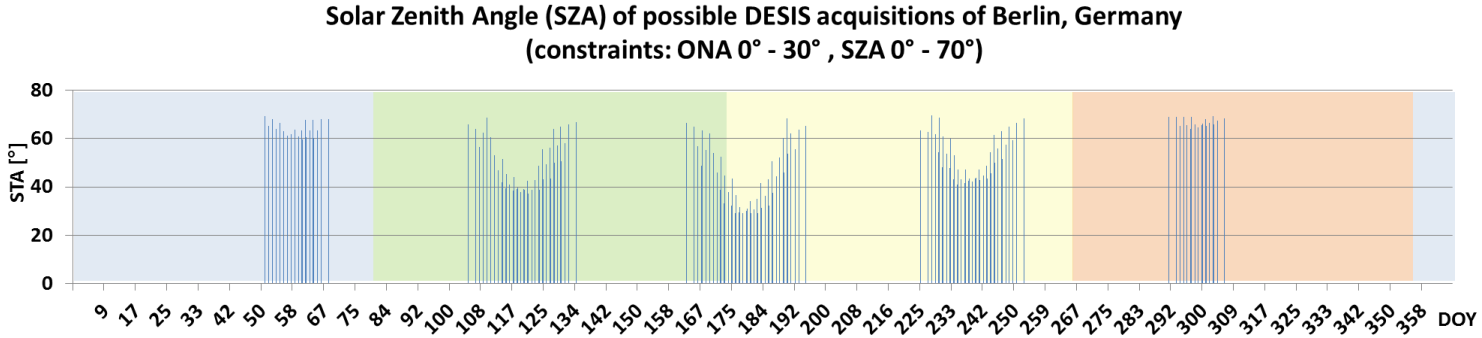


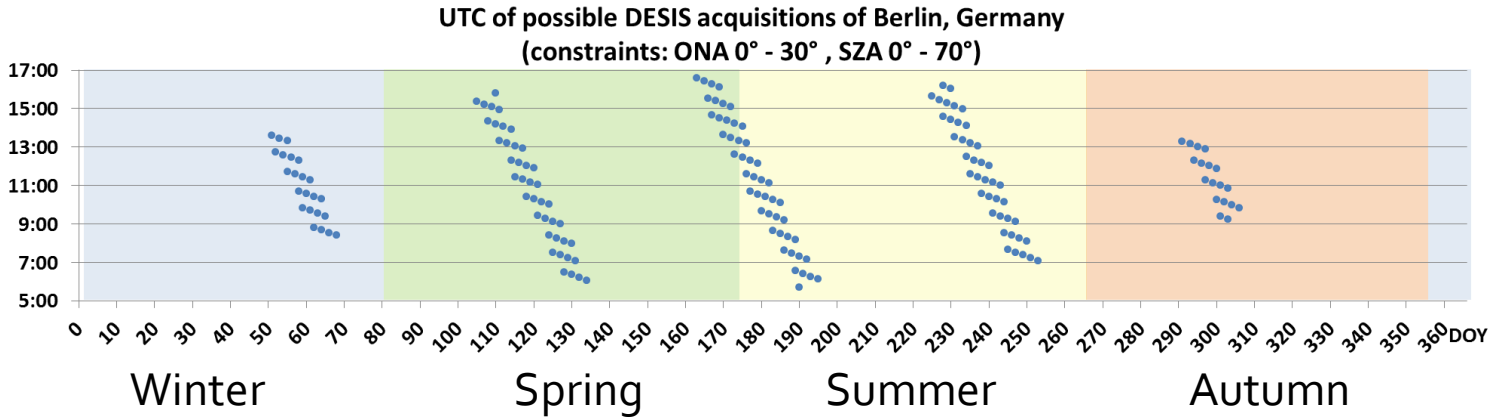
ISS Orbit constraints

- Possible acquisition for Berlin, Germany simulated
- Using ISS orbit data from 2016
- Considers the MUSES/DESIS tilting capabilities
- Daytime overpasses only
- Maximum solar zenith angle of 70°
- Observations 90° orthogonal to the ground track
- Off-Nadir viewing angle < 30°

See also:
Huemmrich et al. (2017). ISS as a Platform for Optical Remote Sensing of Ecosystem Carbon Fluxes: A Case Study Using HICO, JSTARS, 10, 10.

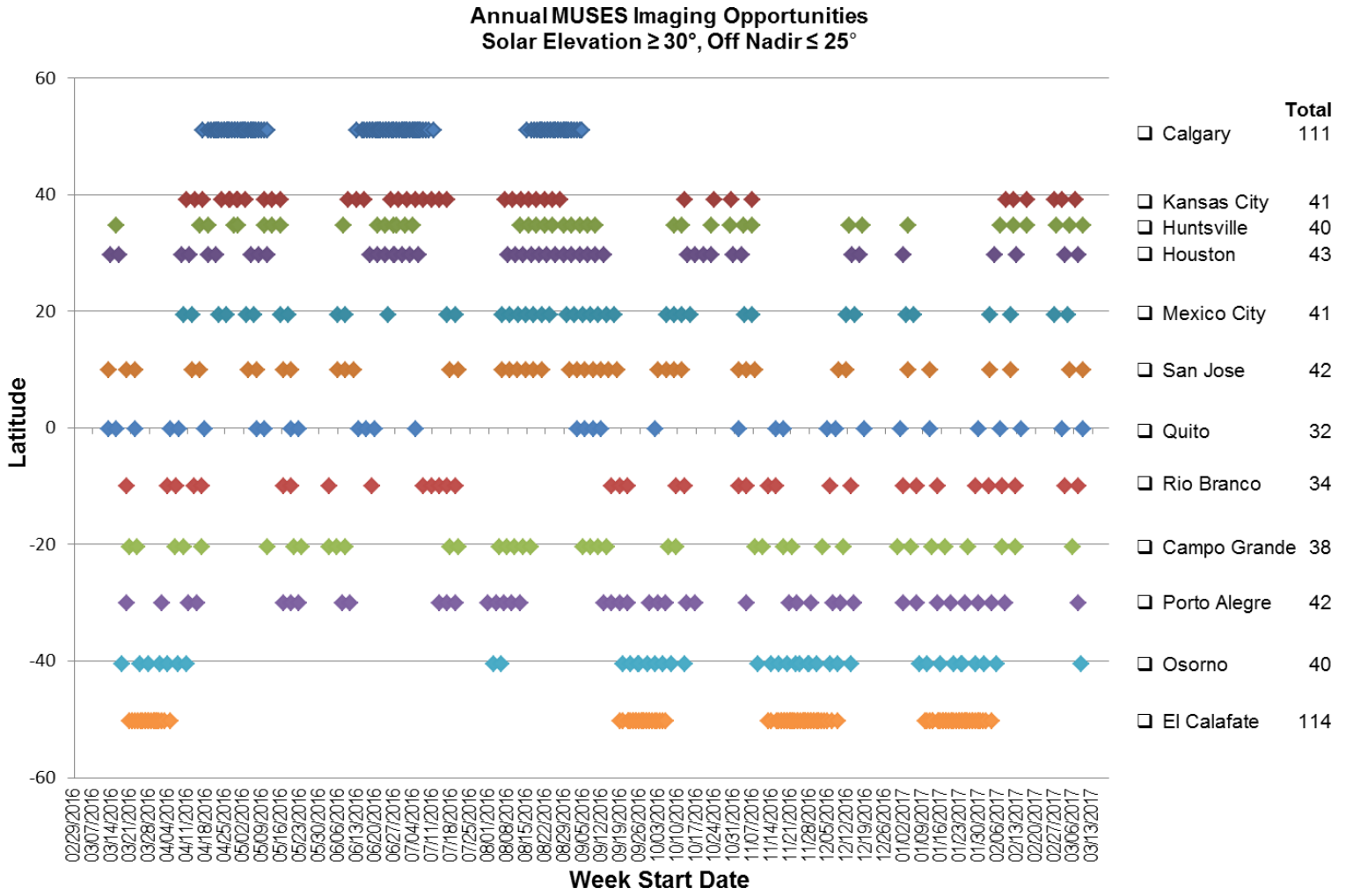






ISS Orbit constraints

Orbit analysis provided by Teledyne



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DESIS Data Access – General Constraints

- Commercial use: Teledyne Brown Engineering (TBE)
- DLR distributes data for scientific and humanitarian purposes - bound to contractual constraints with TBE:
  - **DLR can share DESIS scientific data with other scientific organizations within projects**
  - DLR can't guarantee exclusive rights of data requested and tasked
  - Data use is bound to NOAA License
  - Distribution of 2.55 nm spectral sampled data is subject to NOAA approval
  - Tasking: At least 2000 minutes per calendar year (~166 minutes per month)

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DESIS Data Access – Two Possibilities (via Announcements of Opportunity)

Tasking new DESIS data

- a proposal is requested to understand the basic research question and the amount of data that will be ordered

⇩

Proposal Process

1. Proposal evaluation
2. Task L1A data via TBE – *Earth Sensor Portal*
3. Order your data via DLR EOWEB Portal
4. Download data (L1B, L1C, L2A) via EOWEB Portal

Order archived data

- can be ordered without restrictions

⇩

Only DESIS EOWEB Account required

3. Order your data via DLR EOWEB Portal
4. Download data (L1B, L1C, L2A) via EOWEB Portal

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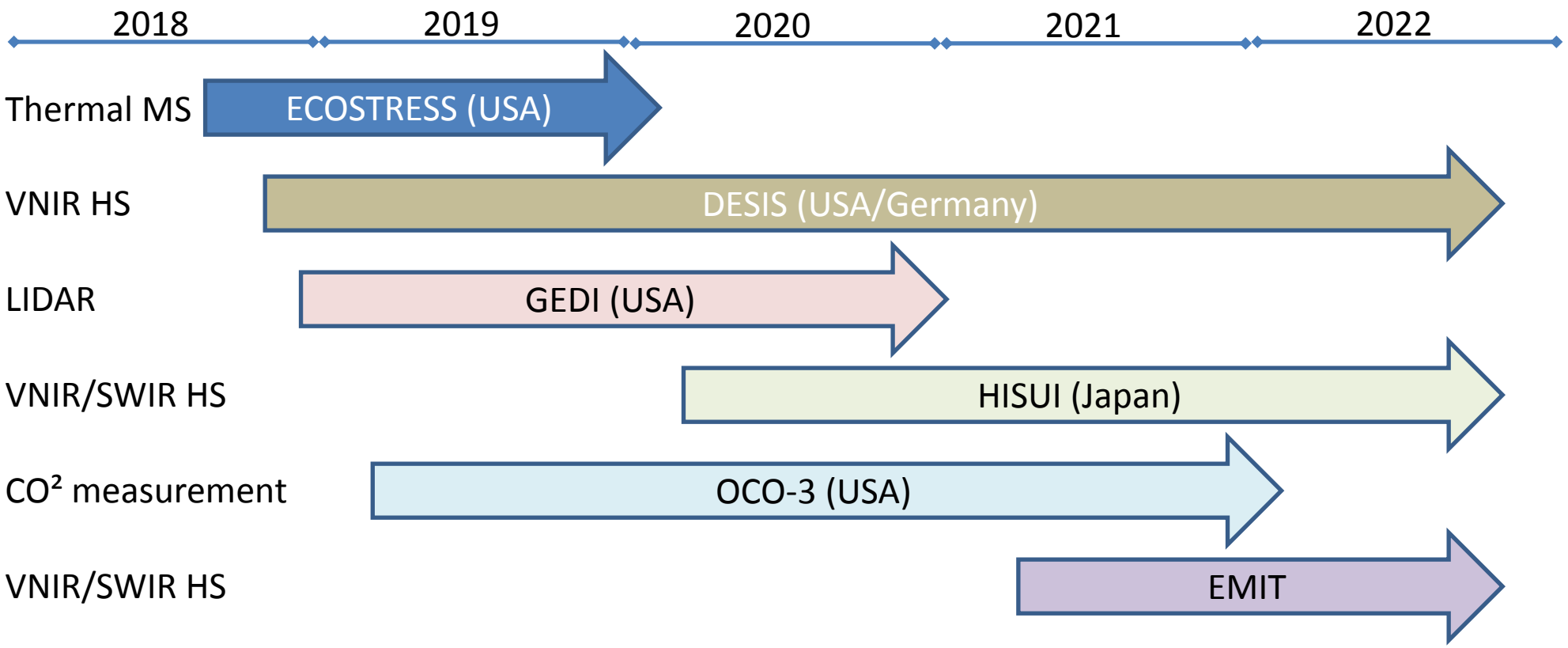
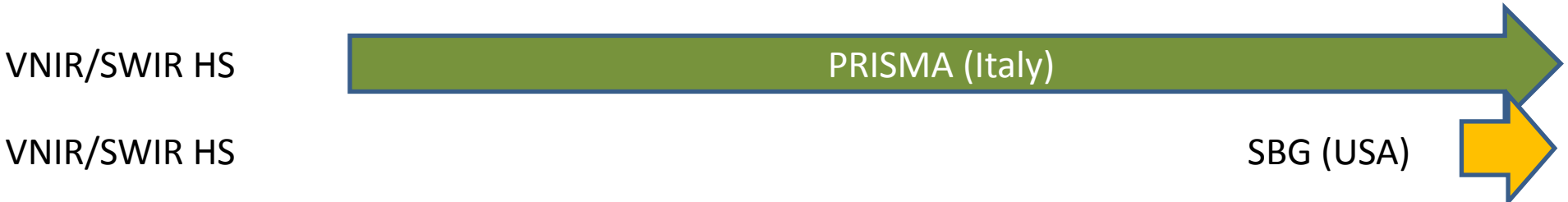
Enabling synergies with other Earth observing missions on ISS – Operation overlap



Other Imaging Spectrometer in Orbit



Experiment!

- Demonstrate the value of an integrated EO approach to address essential questions regarding ecosystem functioning
- Leverage the future development and use of such sensor suites
- Understand the value and performance of the IS sensors on ISS

Enabling synergies with other Earth observing missions on ISS – Relevant science questions

Stavros, E. Natasha; Schimel, David; Pavlick, Ryan; Serbin, Shawn; Swann, Abigail; Duncanson, Laura; Fisher, Joshua B.; Fassnacht, Fabian; Ustin, Susan; Dubayah, Ralph; Schweiger, Anna; Wennberg, Paul (2017). **ISS observations offer insights into plant function,** Nature Ecology & Evolution volume 1, Article number: 0194 (2017); https://doi.org/10.1038/s41559-017-0194.

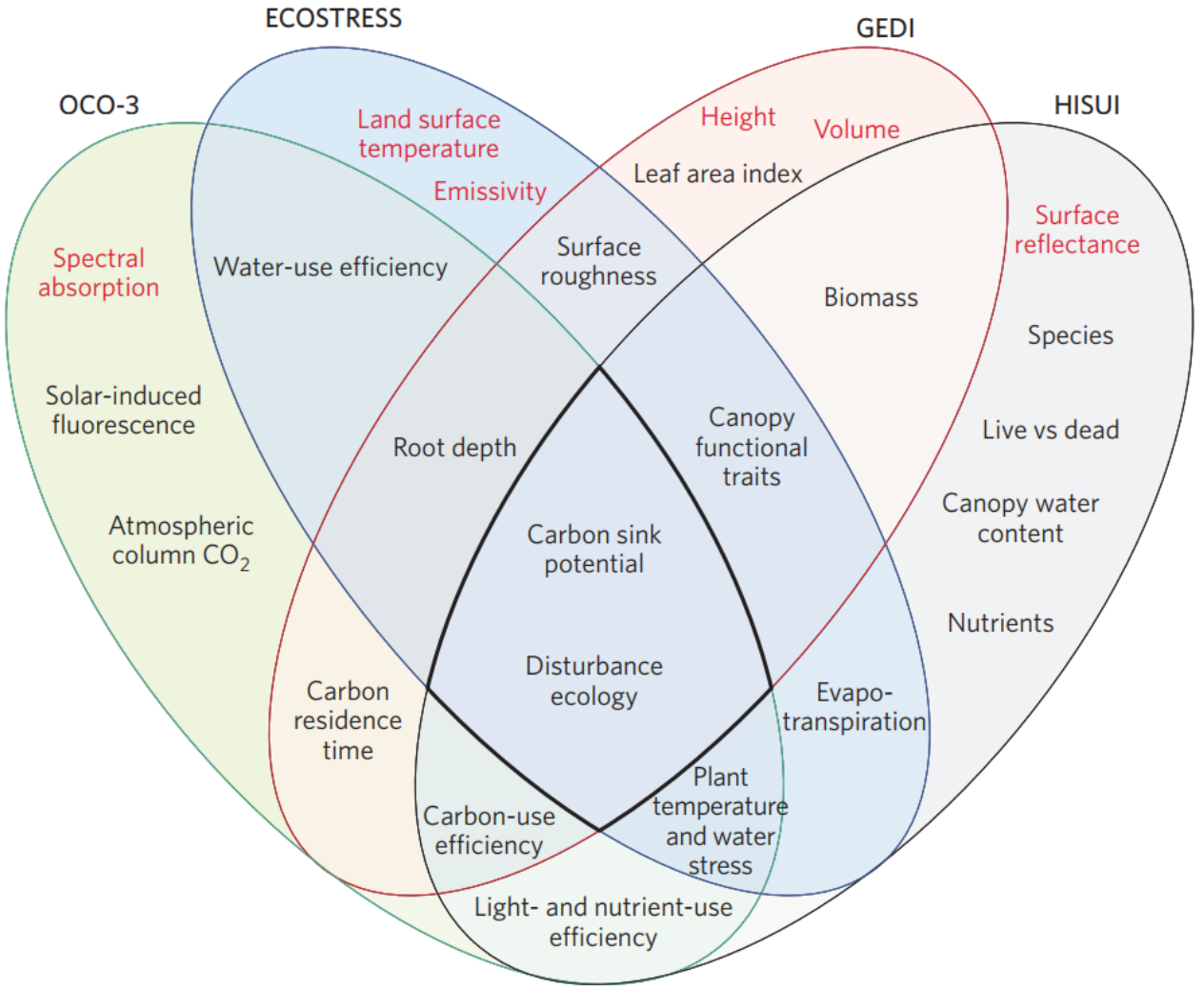


Figure 1 | Spatial and temporal synergy of observations and their applications. A pretzel diagram of observations (red text) from each instrument (coloured shapes) and the synergistic physical parameters that can be derived (black text) when observations are taken at synchronous and complementary spatial and temporal resolutions.

NATURE ECOLOGY & EVOLUTION 1, 0194 (2017) | DOI: 10.1038/s41559-017-0194 | www.nature.com/natecolevol

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Enabling synergies with other Earth observing missions on ISS – Suitable test sites

Test site requirement:

- Relevant for the above stated research questions
- Should be well equipped with suitable in-situ instruments
- Excellent expert knowledge available
- Possibility to share in-situ and other relevant data
- Part of a larger test site network (TERN, LTER, NEON, etc.)

Location of CEOS Land Product Validation (LPV) Supersites (https://lpvs.gsfc.nasa.gov/LPV_Supersites/LPVsites.html)

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Summary

- DESIS is a pushbroom imaging spectrometer covering a spectral range of 400 nm up to 1000 nm (VNIR) and based on a modified Offner design for the spectrometer
- Onboard the ISS – complex orbit characteristics
- Data available for scientific purposes in cooperation with DLR (in the operational phase)
- DLR supports initiatives that explore the synergistic use of Earth observing instruments on ISS and other imaging spectroscopy missions (e.g. PRISMA)

Thank you for your attention!

DESIS Ground Segment Manager

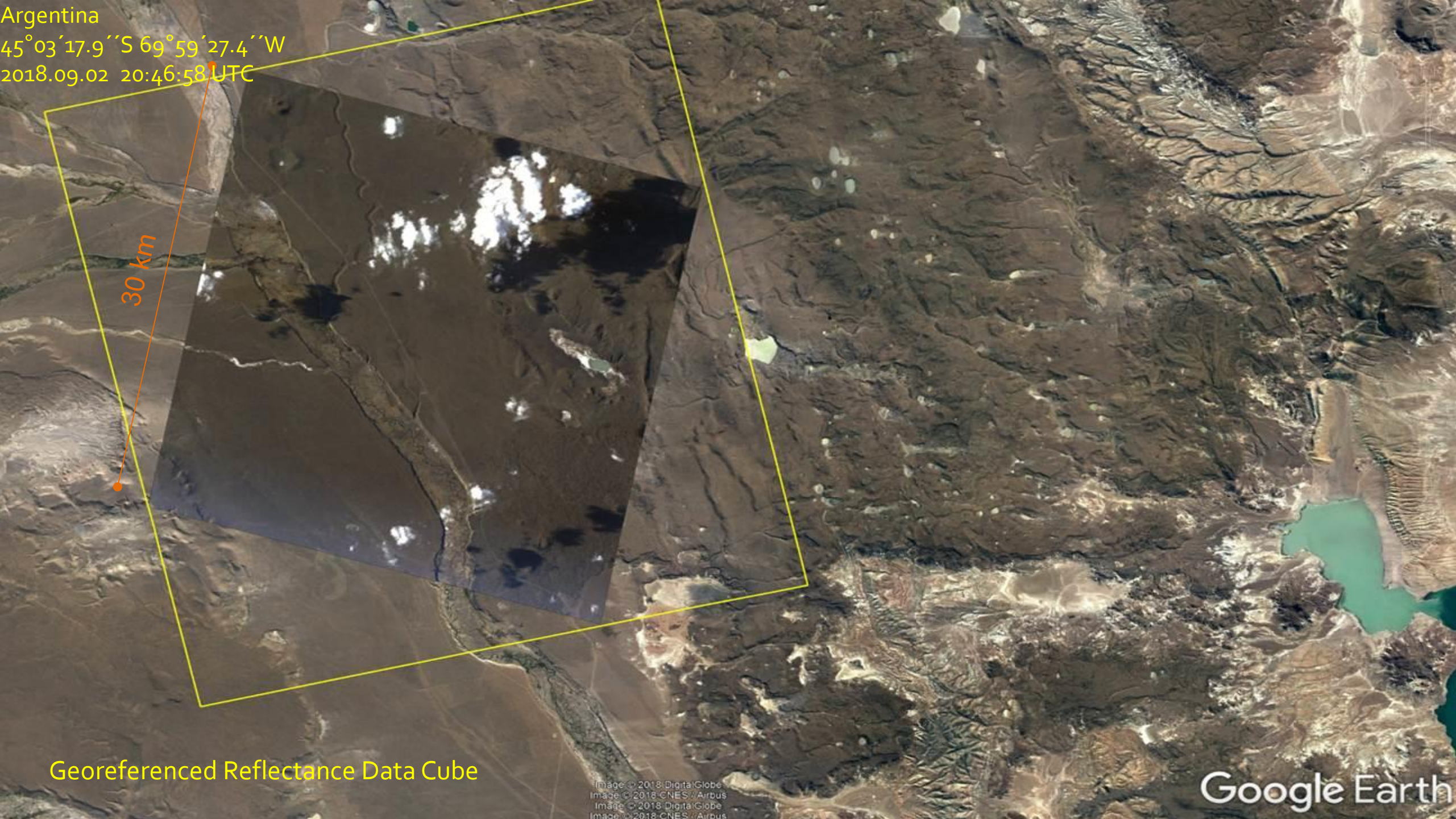
Dr. Rupert Müller

Rupert.Mueller@dlr.de

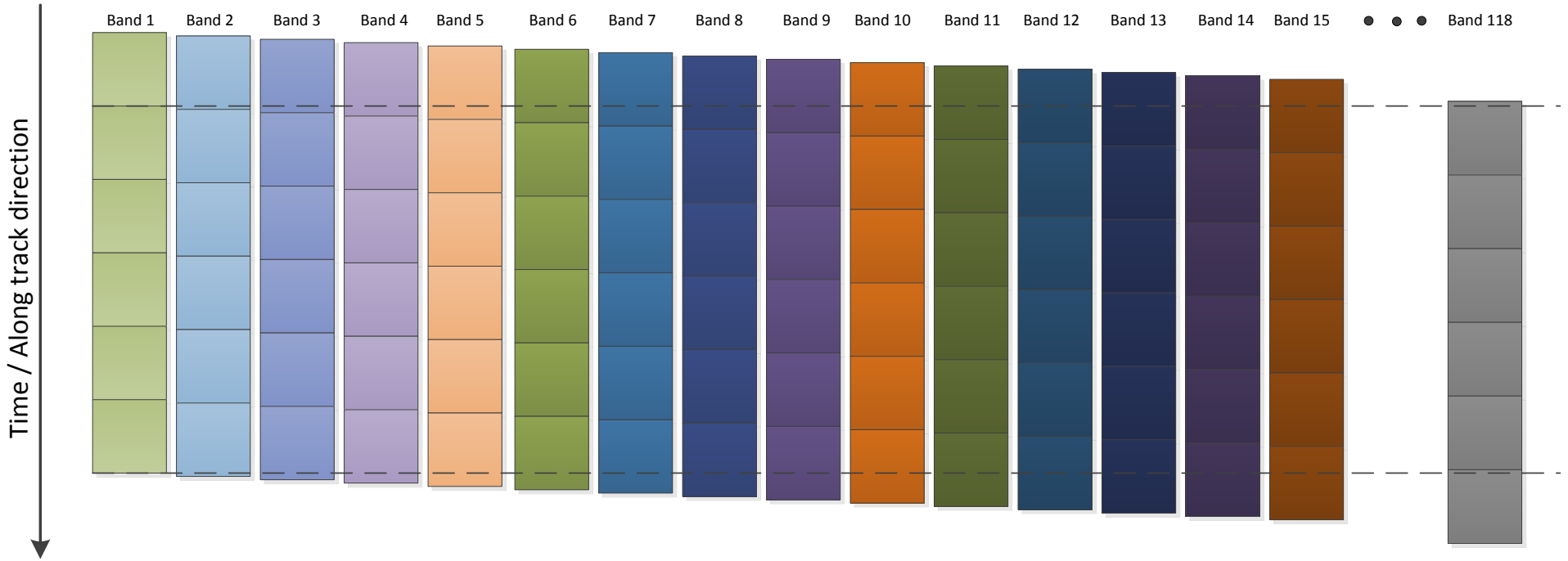
DESIS Science Coordinator

Dr. Uta Heiden

Uta.heiden@dlr.de


Argentina
45°03´17.9´´S 69°59´27.4´´W
2018.09.02 20:46:58 UTC
30 km
Georeferenced Reflectance Data Cube
Image © 2018 DigitalGlobe
Image © 2018 CNES / Airbus
Image © 2018 DigitalGlobe
Image © 2018 CNES / Airbus
Google Earth

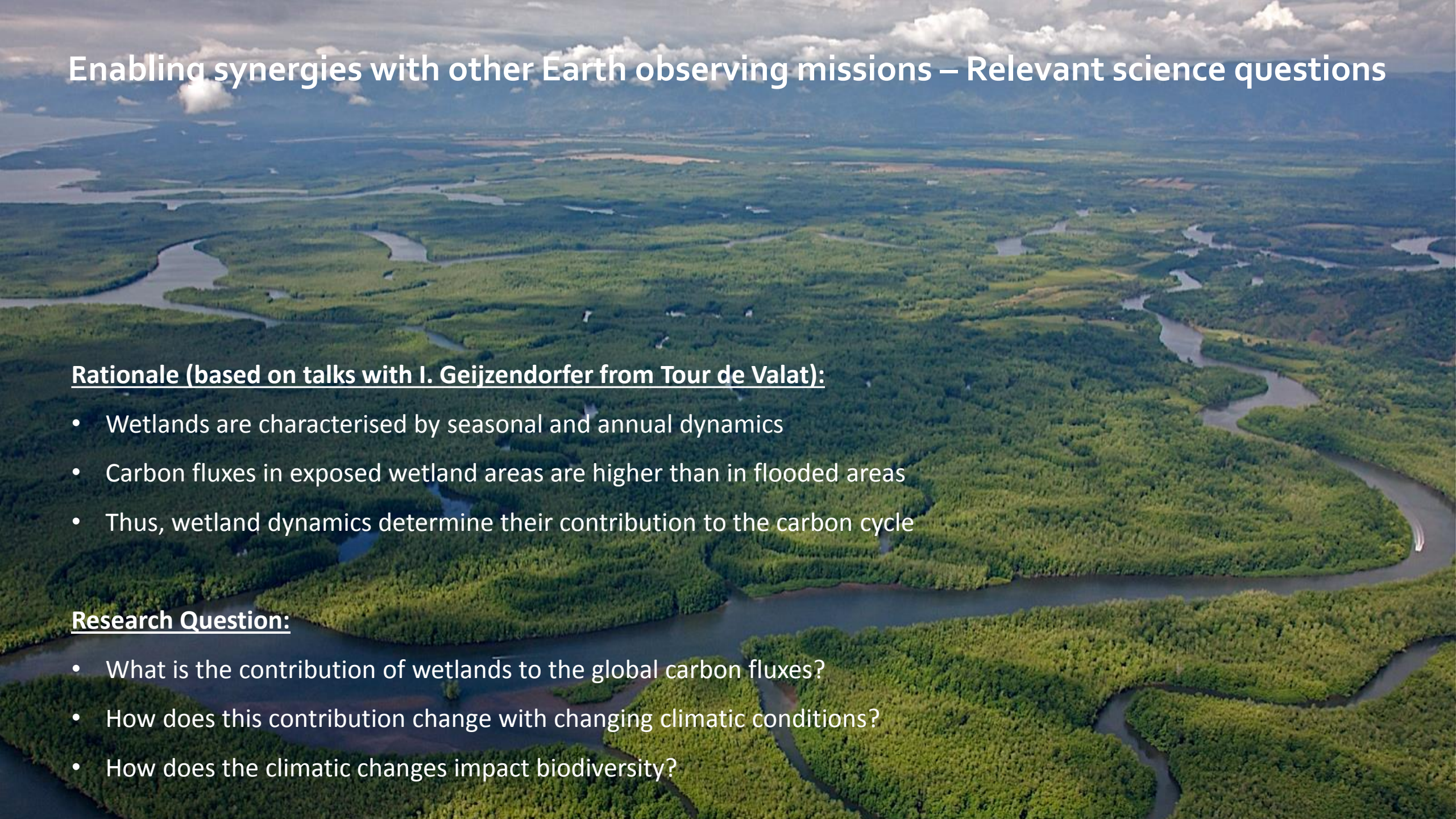
DESIS Data Processing
Rolling Shutter



- DESIS will be the first multiband spaceborne sensor featuring a rolling shutter
- Each consecutive band is observed at a slightly delayed position on ground

- Need to re-sample data to have all wavelength registered values at the same position on ground
- Correction integrated in processor

Enabling synergies with other Earth observing missions – Relevant science questions



Rationale (based on talks with I. Geijzendorfer from Tour de Valat):

- Wetlands are characterised by seasonal and annual dynamics
- Carbon fluxes in exposed wetland areas are higher than in flooded areas
- Thus, wetland dynamics determine their contribution to the carbon cycle

Research Question:

- What is the contribution of wetlands to the global carbon fluxes?
- How does this contribution change with changing climatic conditions?
- How does the climatic changes impact biodiversity?